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DIGITAL SPECTRA SYNTHESIS

By

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Fort Rucker, AL 36362

October 1976

Presentation
for
Optical Society of America
Tucson, Arizona

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Digital spectra synthesis is a digitizing technique for spectra synthesis which offers certain preferential and desirable features of the relative energy spectral distribution by compositing two or more known electromagnetic radiation spectra. One can derive and thus predict the chromaticity properties of any given new spectrum. Several experimental examples will be given. The CIE chromaticity characteristics of several resultant spectra will be derived and analyzed. The main component for the digitizing processes is the Tektronix Digital Processing Oscilloscope - Rapid Scan Spectrometer (DPO - RSS) with an

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automatic data processing and acquisition unit with PDP 11/05 minicomputer. The operation of this system will be discussed in detail. Several entrance components including the double and the triple swan-neck fiber optics are being used in this experiment.

Due to the constraints of physical and chemical nature of electro-magnetic radiation, the relative energy power distribution of a given radiator at a specified set of conditions is, in general, confined to a definite waveform and a colorimetric characteristic with limited statistical variations. For example, Figure 1 shows the spectrum of a common fluorescent lamp which exhibits mercury emission lines at approximately 436, 546, and 578 nm. Figure 2 shows the spectrum of a common tungsten lamp which does not have any emission line. We notice that the fluorescent spectrum contains higher energy at the lower end of the distribution while the energy distribution of the tungsten spectrum increases gradually toward the higher end. Suppose one wishes to have a source with approximately equal energy distribution throughout the spectrum; he has at least two alternative choices. He may select another source such as a Macbeth daylight lamp or he may use the synthesis method[1].

An example of the synthesis method is shown in Figure 3 which is the resultant spectral distribution curve of the tungsten and the fluorescent lamp. It represents a preferential combination of two known spectral distributions. Another example, shown in Figure 4, is the combinatory spectral distribution between the tungsten and the mercury lamps. Notice that the emission lines of the mercury spectrum are identical to those of the fluorescent spectrum shown in Figure 1 since both of them were enveloped with certain compositions of mercury vapor. Now the question arises as to what extent the principle of linear additivity law holds for the energy summation and for the characteristics

of the chromaticity coordinates in the process of spectral syntheses with digital computation.

The experimental design[2] is schematically shown in Figure 5. Two light sources were arranged such that the entrance beams were slightly deviated from the optical axis. We chose the mirror system to reflect one of the light sources because physically if we put both sources side by side along the optical axis, the beam deviations would be beyond the sensitivity field range of the detector[3]. The detector was the Tektronix Rapid Scan Spectrometer (RSS). The signals were digitized in a Digital Processing Oscilloscope (DPO) and data were stored and manipulated in a PDP 11/05 minicomputer. Several peripheral pieces of equipment, such as a graphic display, a teletype and a hard copier were indicated as accessories. A computer program[4] that computed the 1931 CIE chromaticity coordinates and plotted the corresponding diagram with Planckian color temperature was used to obtain the spectral locus of the source. A detailed description of the experimental design was given elsewhere[1,2].

The spectral waveform from 400 to 800 nm was digitized into 512 points. This enabled us to manipulate digitally various mathematical operations such as the verification of the law of additivity. Figure 6 compares the synthesized spectrum (i.e. combinatory) and the digitally combined spectrum (i.e. linear summed). Notice that the combinatory spectrum is identical to the one in Figure 4. Theoretically, the two spectra in Figure 6 shall be the same provided that the law of additivity

holds for energy summation. Since the RSS was very sensitive, a small movement of the source would change slightly the magnitude of the spectrum. In this particular case, we suspect that the tungsten spectrum changed slightly when the switch was turned on-off.

On the other hand, we have examined the chromaticity coordinate values and found that the percent deviations were negligibly small indeed (Table 1). Figure 7 plotted the spectral loci of tungsten, mercury and their combination on a CIE chromaticity diagram. Table 1 summarized the numerical values for those loci. The percent deviation for x is 0.9374% and for y is 1.4937% which is well within the allowable experimental error. The combinatory locus falls in the geometrical mean of the Hg locus and the tungsten locus. That is, it is on the equal energy locus of the line connecting the Hg locus and the tungsten locus which is shown as a line in Figure 7.

In conclusion, we have employed the synthesis method to create an electromagnetic radiation spectrum in the visible range such that its spectral characterisitcs are preferentially selected. Although deviation in the energy summation seems to be noticeable, it is negligibly small in the evaluation of the chromaticity coordinate values. Thus, we believe that the new synthesized spectrum obeys the law of additivity in both energy summation and the chromaticity characteristics.

REFERENCES

1. Chiou, W.C., USAARL-LR-76-1-7-1 (1975).

2. Another possible arrangement is to use the half-silver beam splitter 45° to the optical axis. A third method which we currently plan to use is to use various geometrical arrangements of fiber optics.

3. The vertical field of view is 9.5°, the horizontal is 8.2°.

4. The computer program was originally supplied by Tektronix, Inc., for the RSS-DPO system. The language used in this program is DPO TEK-BASIC.

5. Chiou, W.C., Applied Optics 14, 2585 (1975).

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TABLE 1 CIE CHROMATICITY COORDINATES

	X	Y
Tungsten	.4847	.4244
Mercury	.3261	.4793
Combination	.4016	.4451
Linear Summed	.4054	.4519
% Deviation	0.9374%	1.4937%

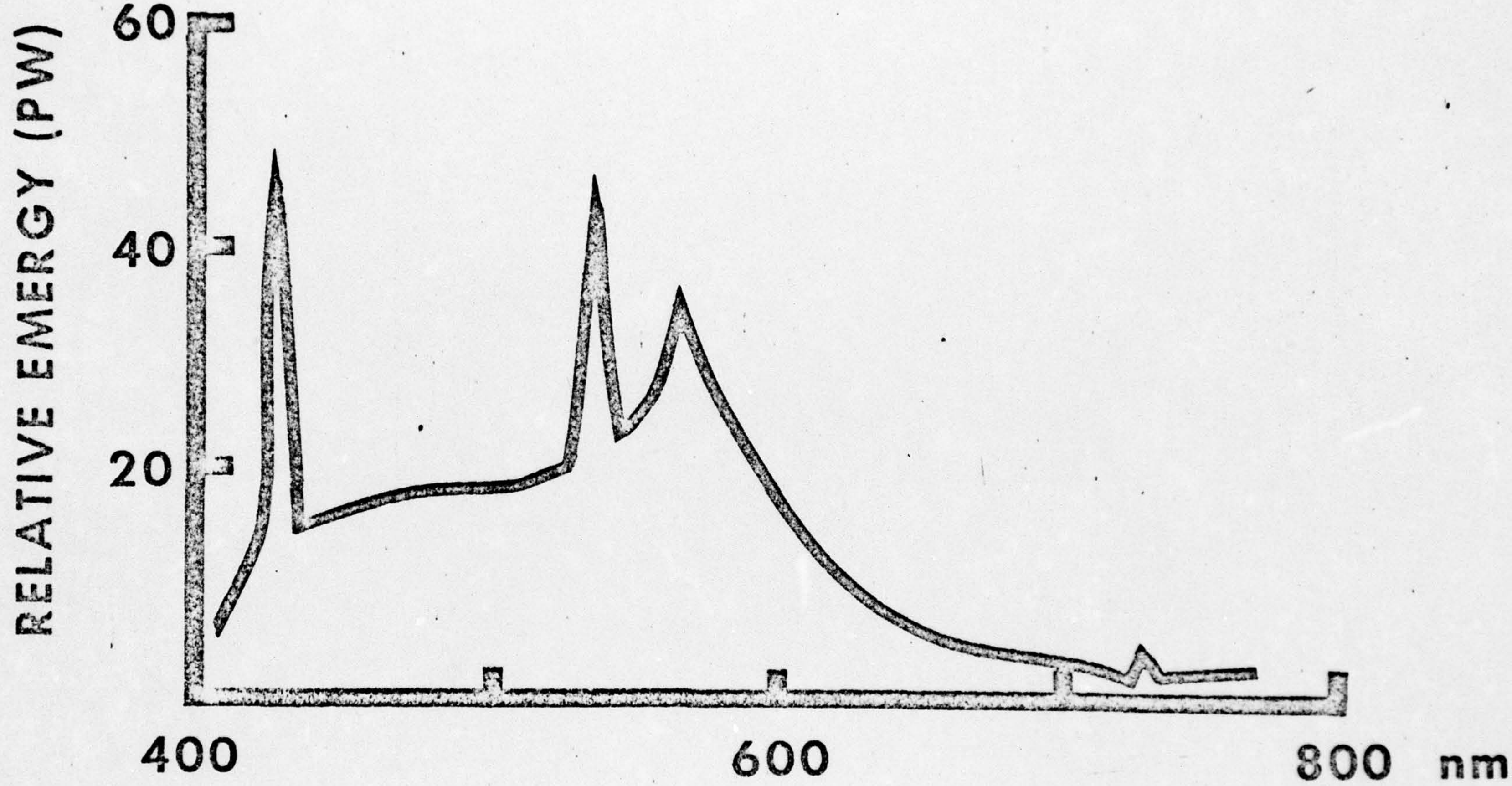

FIGURE 1

FLUORESCENT SPECTRAL POWER DISTRIBUTION

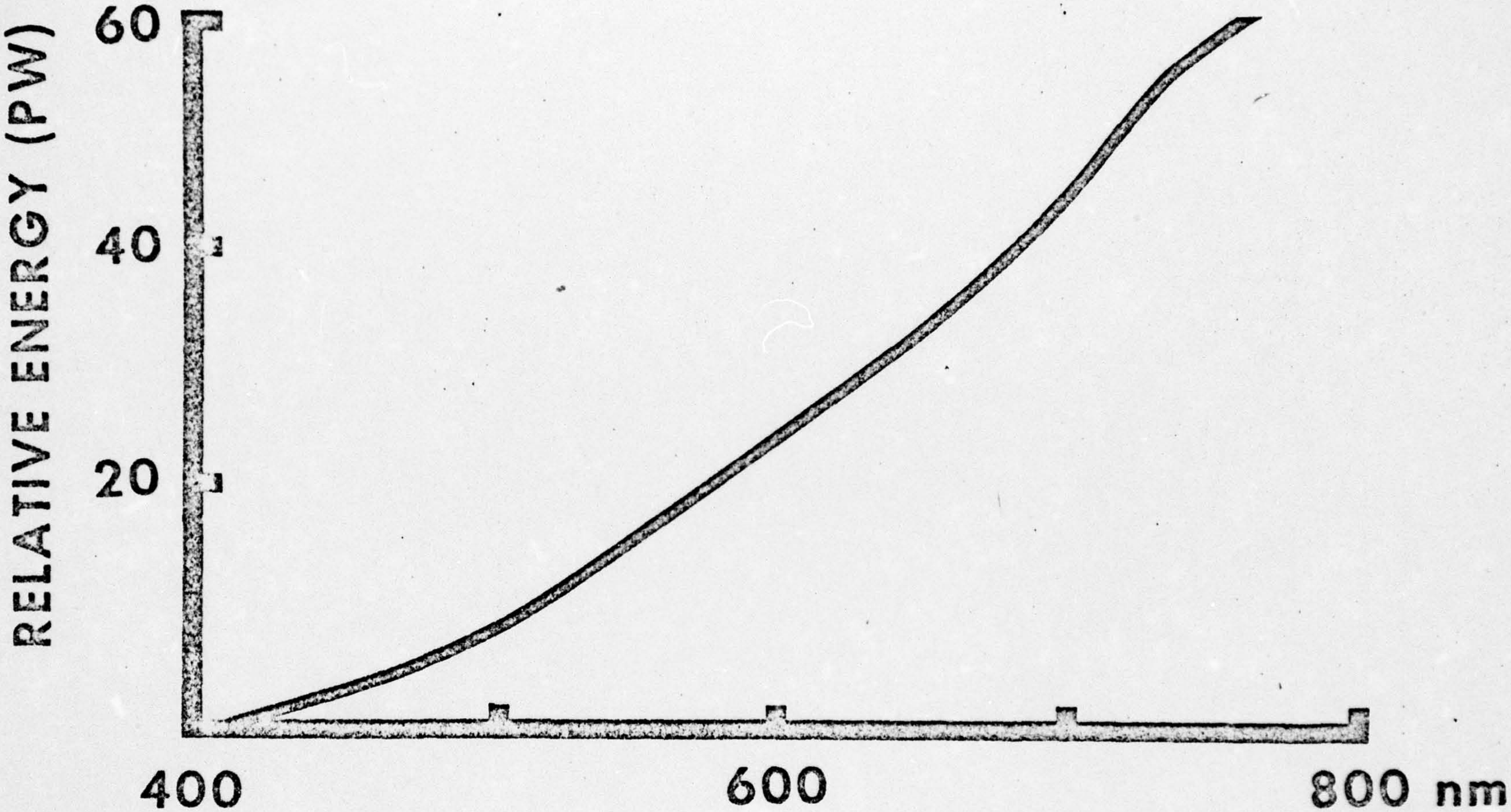

FIGURE 2

TUNGSTEN SPECTRAL DISTRIBUTION

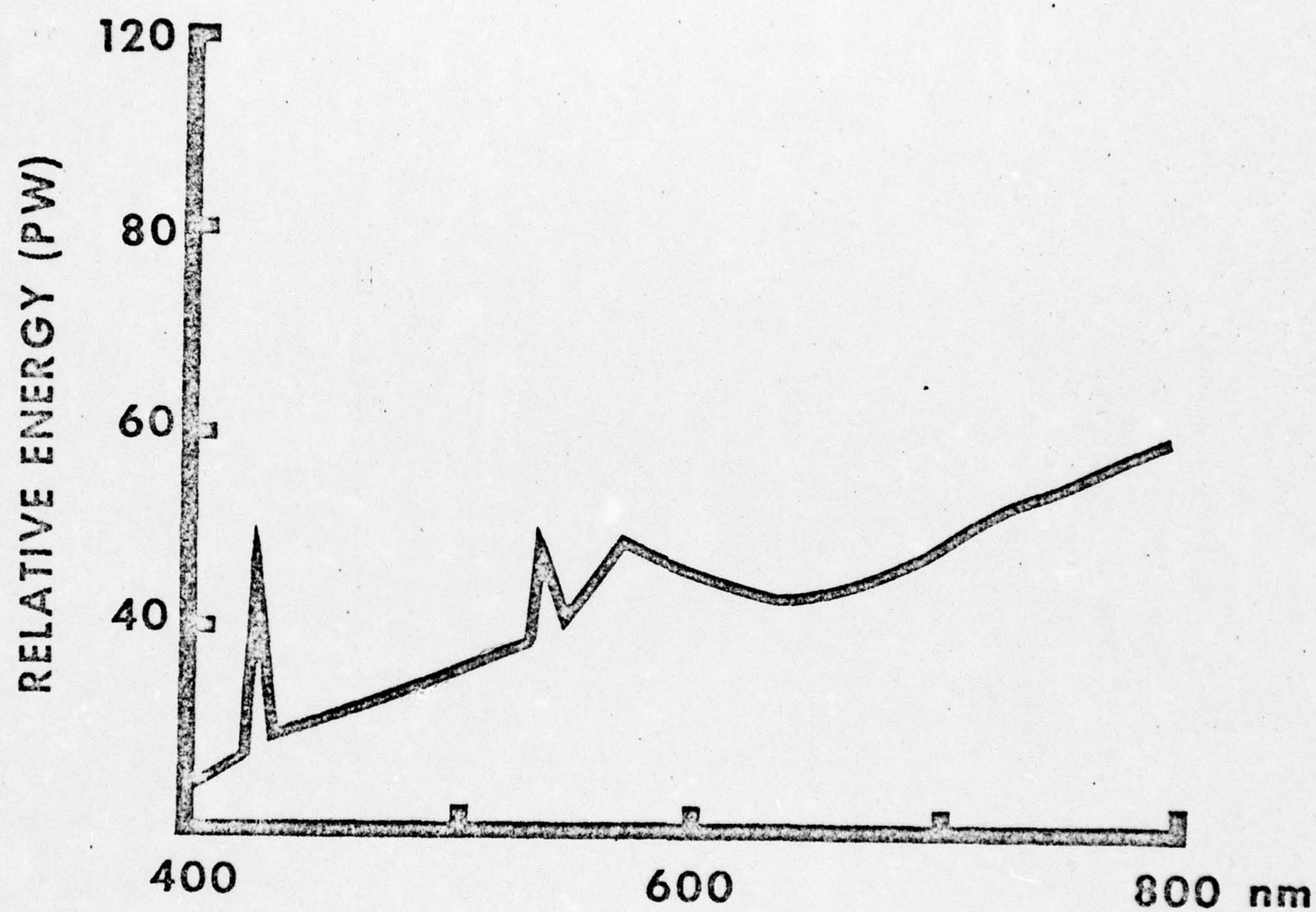

FIGURE 3
RESULTANT TUNGSTEN - FLUORESCENT SPECTRAL CURVE

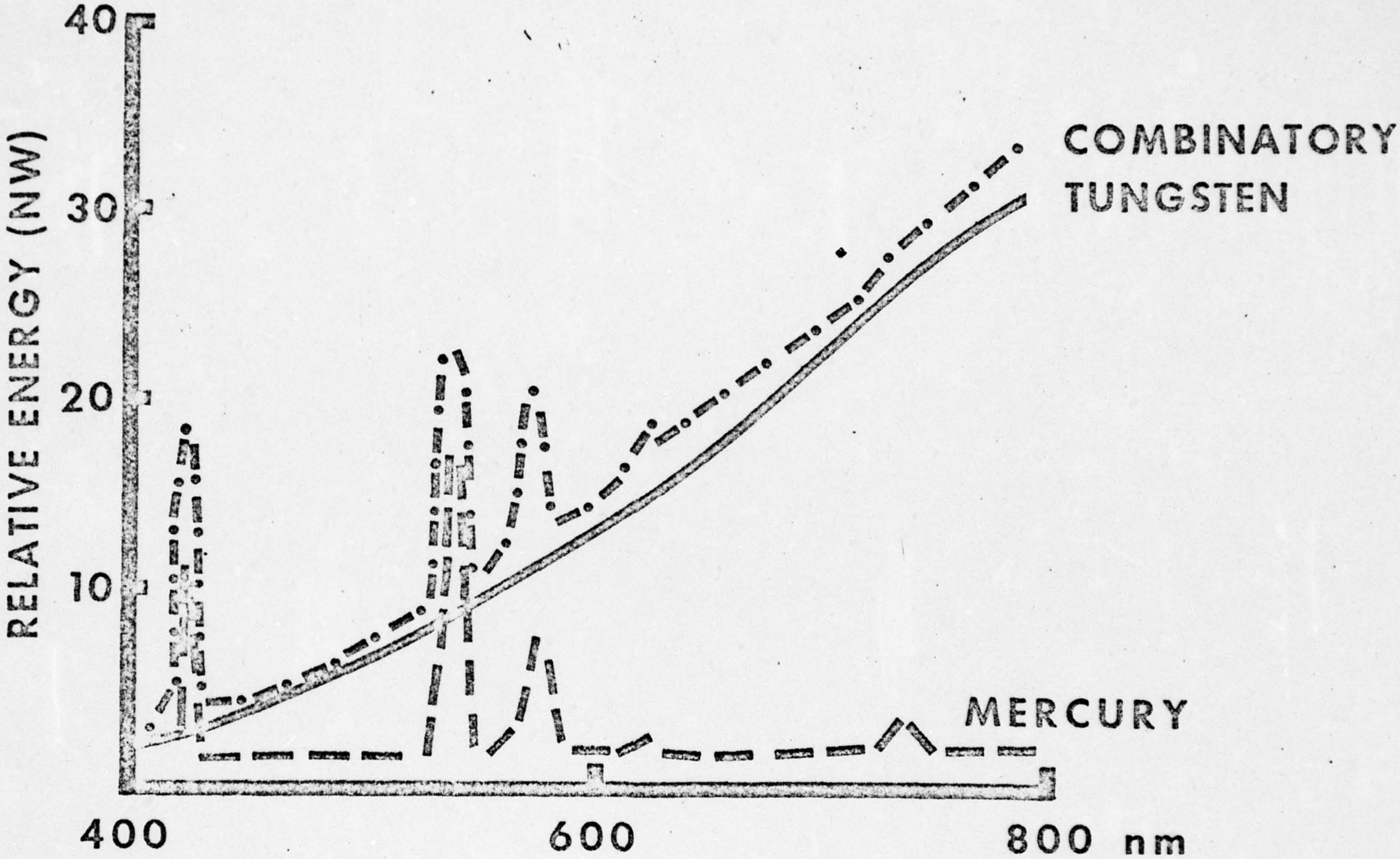

FIGURE 4

TUNGSTEN, MERCURY AND THEIR COMBINATORY SPECTRAL DISTRIBUTION

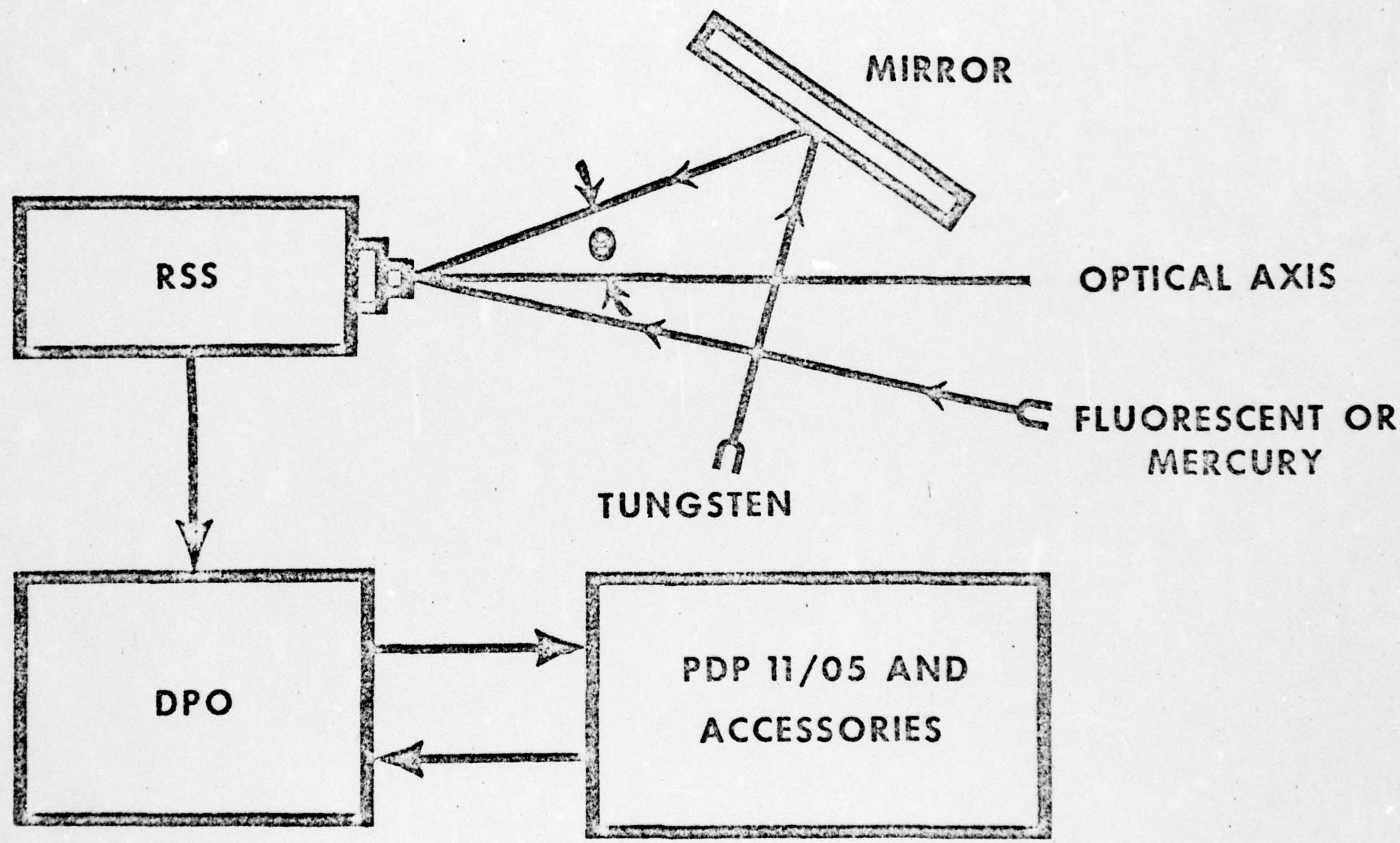

FIGURE 5

BLOCK DIAGRAM FOR MEASUREMENT

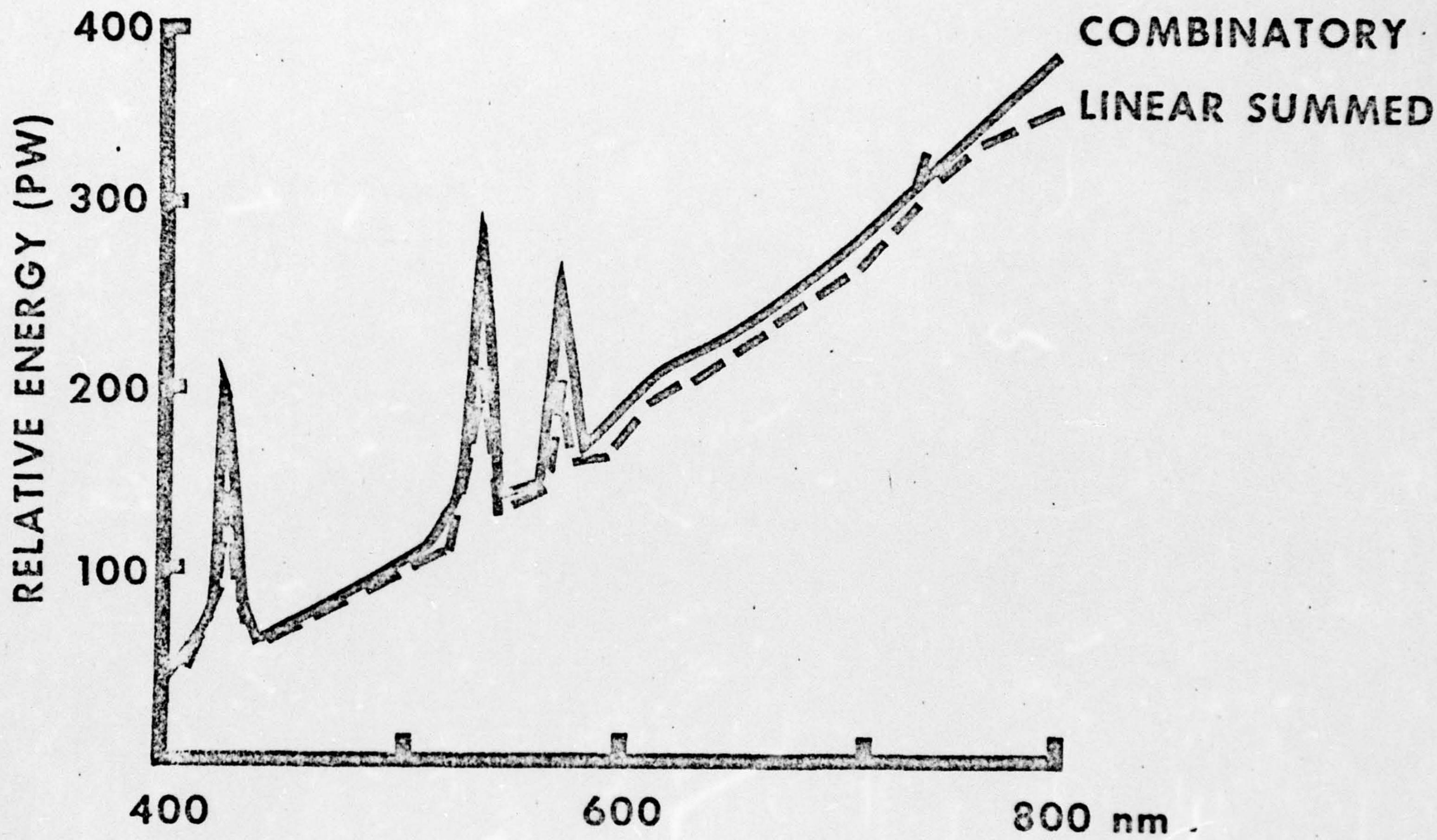

FIGURE 6

COMINATORY VERSUS LINEAR SUMMED SPECTRAL CURVES

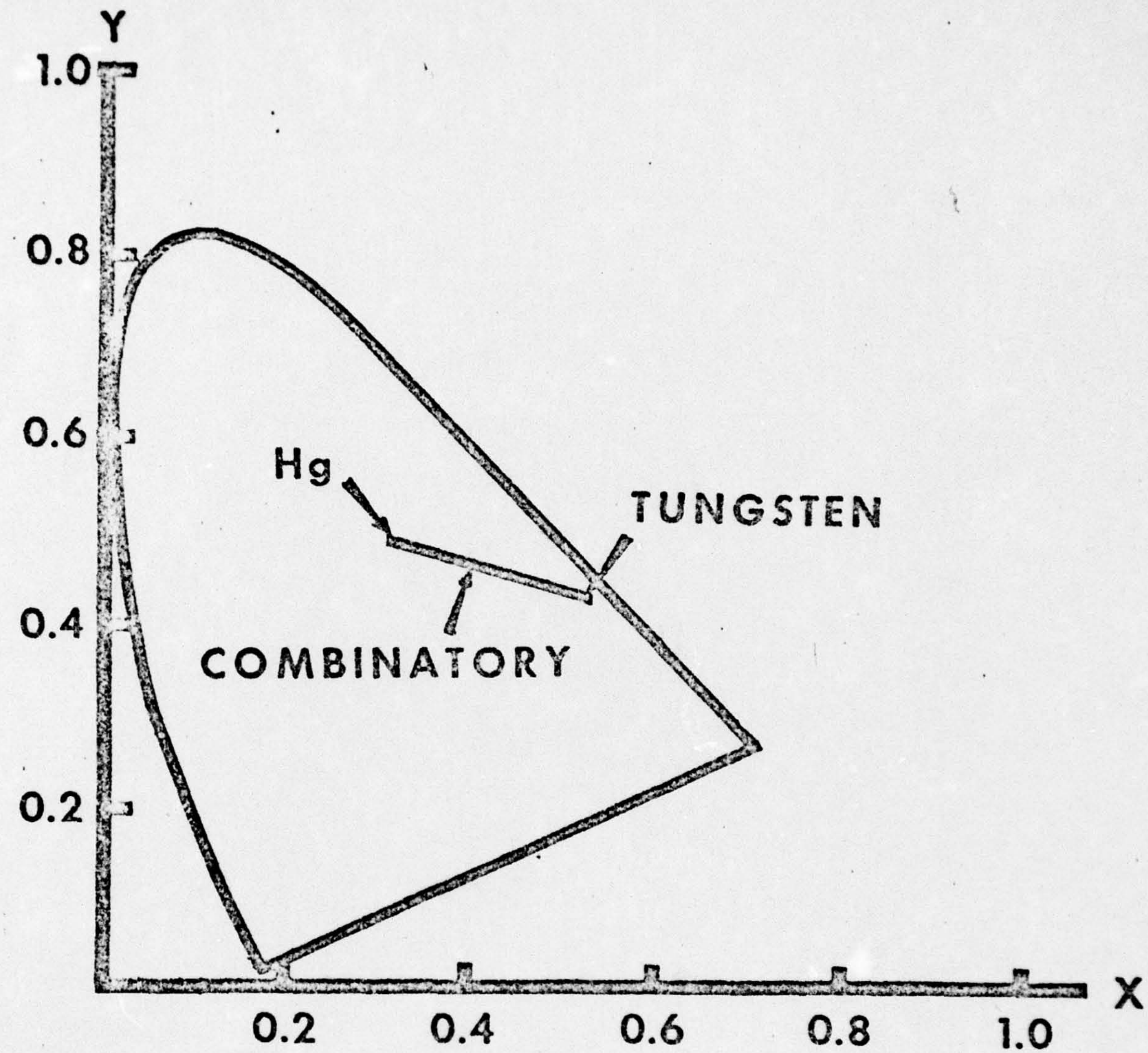

FIGURE 7
CIE CHROMATICITY DIAGRAM
OF TUNGSTEN AND MERCURY